CHAPTER

3 Energy

the BIG idea

Energy has different forms, but it is always conserved.

Key Concepts

SECTION 3.1 **Energy exists in different forms.**
Learn about several different forms of energy.

SECTION 3.2 **Energy can change forms but is never lost.**
Learn about the law of conservation of energy.

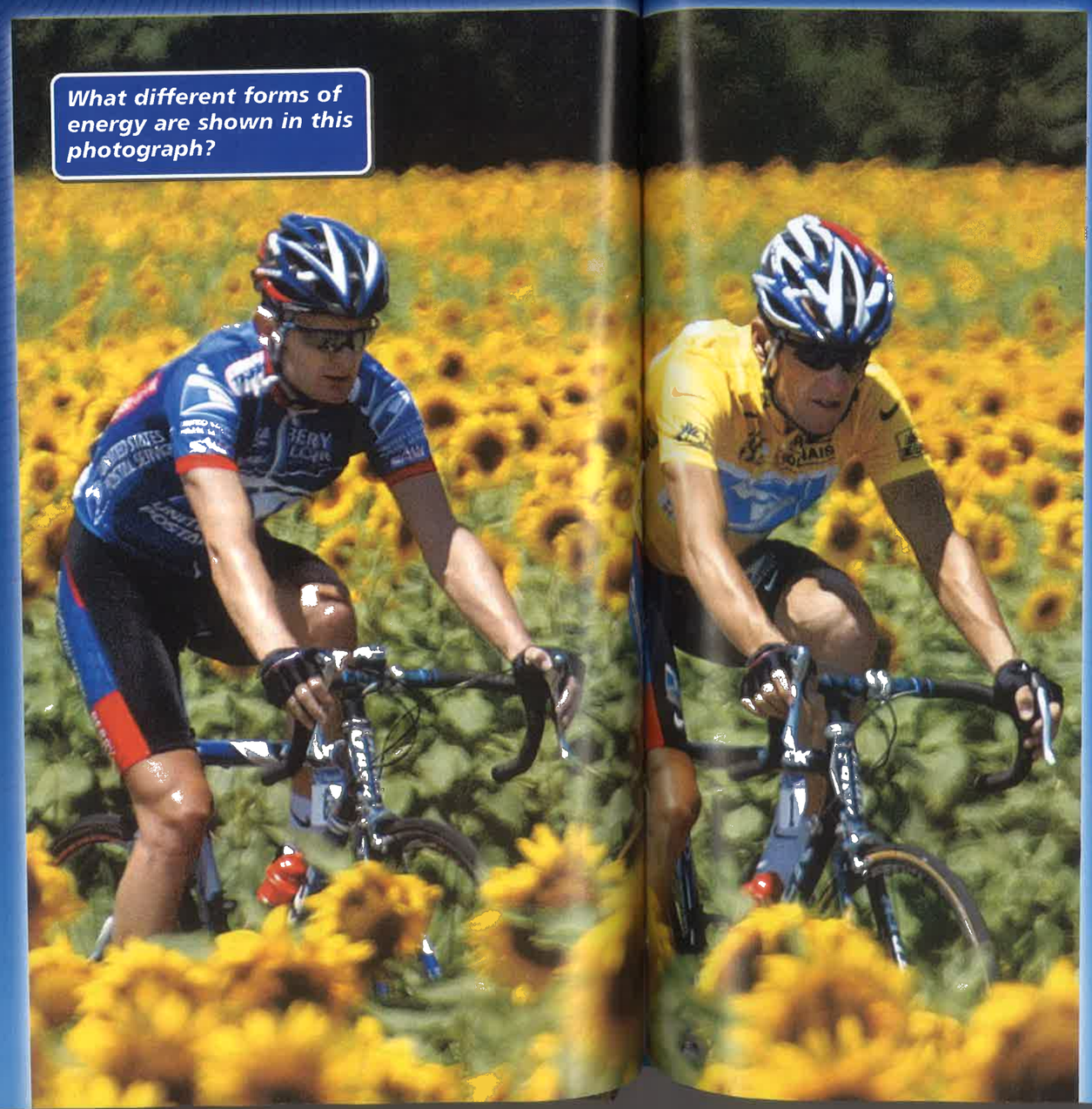
SECTION 3.3 **Technology improves the ways people use energy.**
Learn how technology can be used to make energy conversions more efficient.

Internet Preview

CLASSZONE.COM

Chapter 3 online resources: Content Review, Simulation, Visualization, three Resource Centers, Math Tutorial, Test Practice

What different forms of energy are shown in this photograph?



EXPLORE the BIG idea

A Penny for Your Energy

Chill an empty glass bottle. Immediately complete the following steps: Rub a drop of cooking oil around the rim of the bottle. Place a coin on the rim so the oil forms a seal between the coin and the bottle. Wrap your hands around the bottle.

Observe and Think What happened to the coin? What do you think caused this to happen?

Hot Dog!

Cover a piece of cardboard with aluminum foil, and bend it into the shape of a U. Poke a wooden skewer through a hot dog, and through each side of the cardboard. Push corks over both ends of the skewer so the cardboard does not flatten out. Place your setup in direct sunlight for 30 minutes.

Observe and Think What happened to the hot dog? Were there any changes you had to make while the hot dog was in sunlight?

Internet Activity: Energy

Go to **ClassZone.com** to investigate the relationship between potential energy and kinetic energy.

Observe and Think How did you change potential energy? How do these changes affect kinetic energy?

NSTA SCILINKS scilinks.org

Forms of Energy **Code: MDL063**

CHAPTER 3

Getting Ready to Learn

CONCEPT REVIEW

- Matter has mass and is made of tiny particles.
- Matter can be changed physically or chemically.
- A change in the state of matter is a physical change.

VOCABULARY REVIEW

matter p. 9
mass p. 10
atom p. 16
physical change p. 44
chemical change p. 46

CONTENT REVIEW
CLASSZONE.COM
Review concepts and vocabulary.

TAKING NOTES

MIND MAP

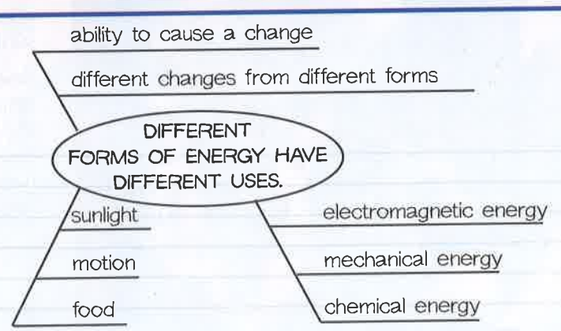
Write each main idea, or blue heading, in an oval; then write details that relate to each other and to the main idea. Organize the details so that each spoke of the web has notes about one part of the main idea.

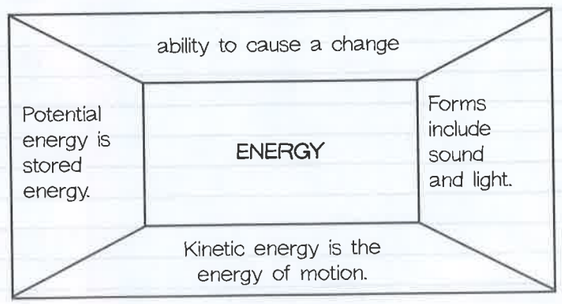
VOCABULARY STRATEGY

Write each new vocabulary term in the center of a **frame game** diagram. Decide what information to frame it with. Use examples, descriptions, parts, sentences that use the term in context, or pictures. You can change the frame to fit each term.

See the Note-Taking Handbook on pages R45–R51.

SCIENCE NOTEBOOK





KEY CONCEPT

3.1 Energy exists in different forms.

BEFORE, you learned

- All substances are made of matter
- Matter has both physical and chemical properties
- Matter can exist in different physical states

NOW, you will learn

- How energy causes change
- About common forms of energy
- About kinetic energy and potential energy

VOCABULARY

energy p. 72
kinetic energy p. 74
potential energy p. 75

EXPLORE Energy

How can you demonstrate energy?

PROCEDURE

1. Fill the bowl halfway with sand. Place the bowl on the floor as shown. Make sure the sand is level.
2. Place a pebble and a rock near the edge of a table above the bowl of sand.
3. Gently push the pebble off the table into the sand. Record your observations.
4. Remove the pebble, and make sure the sand is level. Gently push the rock off the table into the sand. Record your observations.

MATERIALS

- large plastic bowl
- sand
- pebble
- rock

WHAT DO YOU THINK?

- What happened to the sand when you dropped the pebble? when you dropped the rock?
- How can you explain any differences you observed?

Different forms of energy have different uses.

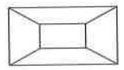
Energy takes many different forms and has many different effects. Just about everything you see happening around you involves energy. Lamps and other appliances in your home operate on electrical energy. Plants use energy from the Sun to grow. You use energy provided by the food you eat to carry out all of your everyday activities—eating, exercising, reading, and even sitting and thinking. In this chapter, you will learn what these and other forms of energy have in common.

Energy

All forms of energy have one important point in common—they cause changes to occur. The flow of electrical energy through a wire causes a cool, dark bulb to get hot and glow. The energy of the wind causes a flag to flutter.

You are a source of energy that makes changes in your environment. For example, when you pick up a tennis racquet or a paintbrush, you change the position of that object. When you hit a tennis ball or smooth paint on a canvas, you cause further changes. Energy is involved in every one of these actions. At its most basic level, **energy** is the ability to cause change.

VOCABULARY
Remember to use a frame game diagram for *energy* and other vocabulary terms.



CHECK YOUR READING Provide your own example of energy and how it causes a change.

The photograph below shows a city street. All of the activities that take place on every street in any city require energy, so there are many changes taking place in the picture. Consider one of the cars. A person's energy is used to turn the key that starts the car. The key's movement starts the car's engine and gasoline begins burning. Gasoline provides the energy for the car to move. The person's hand, the turning key, and the burning gasoline all contain energy that causes change.

The motion of the cars and the glow of the streetlights are changes produced by energy.

Forms of Energy

Scientists classify energy into many forms, each of which causes change in a different way. Some of these forms are described below.

Mechanical Energy The energy that moves objects is mechanical energy. The energy that you use to put a book on a shelf is mechanical energy, as is energy that a person uses to turn a car key.

Sound Energy Sound results from the vibration of particles in a solid, liquid, or gas. People and other animals are able to detect these tiny vibrations with structures in their ears that vibrate due to the sound. So, when you hear a car drive past, you are detecting vibrations in the air produced by sound energy. Sound cannot travel through empty space. If there were no air or other substance between you and the car, you would not hear sounds from the car.

Chemical Energy Energy that is stored in the chemical composition of matter is chemical energy. The amount of chemical energy in a substance depends on the types and arrangement of atoms in the substance. When wood or gasoline burns, chemical energy produces heat. The energy used by the cells in your body comes from chemical energy stored in the foods you eat.

Thermal Energy The total amount of energy from the movement of particles in matter is thermal energy. Recall that matter is made of atoms, and atoms combined in molecules. The atoms and molecules in matter are always moving. The energy of this motion in an object is the object's thermal energy. You will learn more about thermal energy in the next chapter.

Electromagnetic Energy Electromagnetic (ih-LEHK-troh-mag-NEHT-ihk) energy is transmitted through space in the form of electromagnetic waves. Unlike sound, electromagnetic waves can travel through empty space. These waves include visible light, x-rays, and microwaves. X-rays are high energy waves used by doctors and dentists to look at your bones and teeth. Microwaves can be used to cook food or to transmit cellular telephone calls but contain far less energy than x-rays. The Sun releases a large amount of electromagnetic energy, some of which is absorbed by Earth.

Nuclear Energy The center of an atom—its nucleus—is the source of nuclear energy. A large amount of energy in the nucleus holds the nuclear particles together. When a heavy atom's nucleus breaks apart, or when the nuclei (NOO-klee-EYE) of two small atoms join together, energy is released. Nuclear energy released from the fusing of small nuclei to form larger nuclei keeps the Sun burning.

CHECK YOUR READING How does chemical energy cause a change? What about electromagnetic energy?

APPLY Where in this photograph can you find chemical, sound, and mechanical energy?

This solar flare releases electromagnetic energy and thermal energy produced by nuclear energy in the Sun.

Kinetic energy and potential energy are the two general types of energy.

RESOURCE CENTER
CLASSZONE.COM
Learn more about kinetic energy and potential energy.

All of the forms of energy can be described in terms of two general types of energy—kinetic energy and potential energy. Anything that is moving, such as a car that is being driven or an atom in the air, has kinetic energy. All matter also has potential energy, or energy that is stored and can be released at a later time.

Kinetic Energy

READING TiP
Kinetic means "related to motion."

The energy of motion is called **kinetic energy.** It depends on both an object's mass and the speed at which the object is moving.

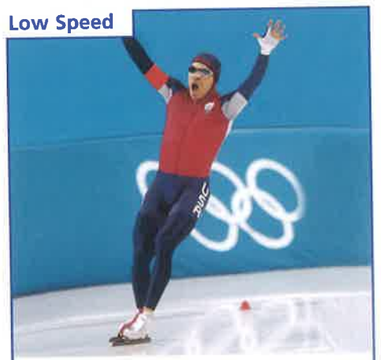
All objects are made of matter, and matter has mass. The more matter an object contains, the greater its mass. If you held a bowling ball in one hand and a soccer ball in the other, you could feel that the bowling ball has more mass than the soccer ball.

- **Kinetic energy increases as mass increases.** If the bowling ball and the soccer ball were moving at the same speed, the bowling ball would have more kinetic energy because of its greater mass.
- **Kinetic energy increases as speed increases.** If two identical bowling balls were rolling along at different speeds, the faster one would have more kinetic energy because of its greater speed. The speed skater in the photographs below has more kinetic energy when he is racing than he does when he is moving slowly.

High Speed

This skater has a large amount of kinetic energy when moving at a high speed.

Low Speed



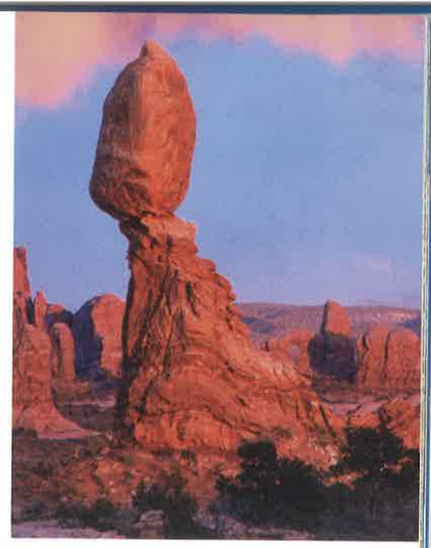
When the same skater is moving more slowly, he has less kinetic energy.

READING VISUALS **APPLY** How could a skater with less mass than another skater have more kinetic energy?

Potential Energy

Suppose you are holding a soccer ball in your hands. Even if the ball is not moving, it has energy because it has the potential to fall. **Potential energy** is the stored energy that an object has due to its position or chemical composition. The ball's position above the ground gives it potential energy.

The most obvious form of potential energy is potential energy that results from gravity. Gravity is the force that pulls objects toward Earth's surface. The giant boulder on the right has potential energy because of its position above the ground. The mass of the boulder and its height above the ground determine how much potential energy it has due to gravity.



Because the boulder could fall, it has potential energy from gravity.

It is easy to know whether an object has kinetic energy because the object is moving. It is not so easy to know how much and what form of potential energy an object has, because objects can have potential energy from several sources. For example, in addition to potential energy from gravity, substances contain potential energy due to their chemical composition—the atoms they contain.

CHECK YOUR READING How can you tell kinetic energy and potential energy apart?

INVESTIGATE Potential Energy

How can you change the amount of potential energy?

DESIGN YOUR OWN EXPERIMENT

Use what you know about potential energy to design an experiment that shows how potential energy can be increased or decreased.

SKILL FOCUS
Designing experiments

MATERIALS
- model car
- meter stick
- weights
- balance
- tape
- cardboard
- books

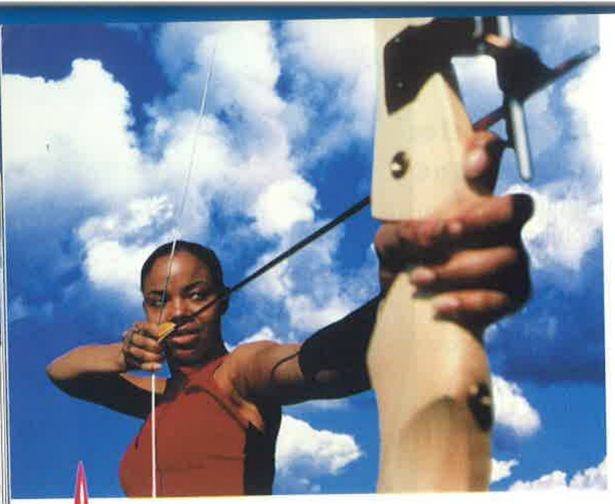
TIME
30 minutes

PROCEDURE

1. Using the materials in the list, design an experiment to investigate the potential energy of the model car. Use the cardboard as a ramp.
2. Write up your hypothesis and your procedure. Remember to include the variables and constants in the experiment.
3. Conduct your experiment and record your results.

WHAT DO YOU THINK?

- What variables did you change? Why?
- How do your results demonstrate a change in potential energy?



Pulling the string, which bends the bow, gives the bow potential energy.

Chemical energy in the fuel of a model rocket engine is potential energy.

Another form of potential energy related to an object's position comes from stretching or compressing an object. Think about the spring that is pushed down in a jack-in-the-box. The spring's potential energy increases when the spring is compressed and decreases when it is released. Look at the bow that is being bent in the photograph on the left. When the bowstring is pulled, the bow bends and stores energy. When the string is released, both the string and the bow return to their normal shape. Stored energy is released as the bow and the string straighten out and the arrow is pushed forward.

When a rock falls or a bow straightens, potential energy is released. In fact, in these examples, the potential energy produced either by gravity or by bending is changed into kinetic energy.

Chemical energy, such as the energy stored in food, is less visible, but it is also a form of potential energy. This form of potential energy depends on chemical composition rather than position. It is the result of the atoms, and the bonds between atoms, that make up the molecules in food. When these molecules are broken apart, and their atoms rearranged through a series of chemical changes, energy is released.

The fuel in a model rocket engine also contains chemical energy. Like the molecules that provide energy in your body, the molecules in the fuel store potential energy. When the fuel ignites in the rocket engine, the arrangement of atoms in the chemical fuel changes and its potential energy is released.

CHECK YOUR READING Why is chemical energy a form of potential energy?

3.1 Review

KEY CONCEPTS

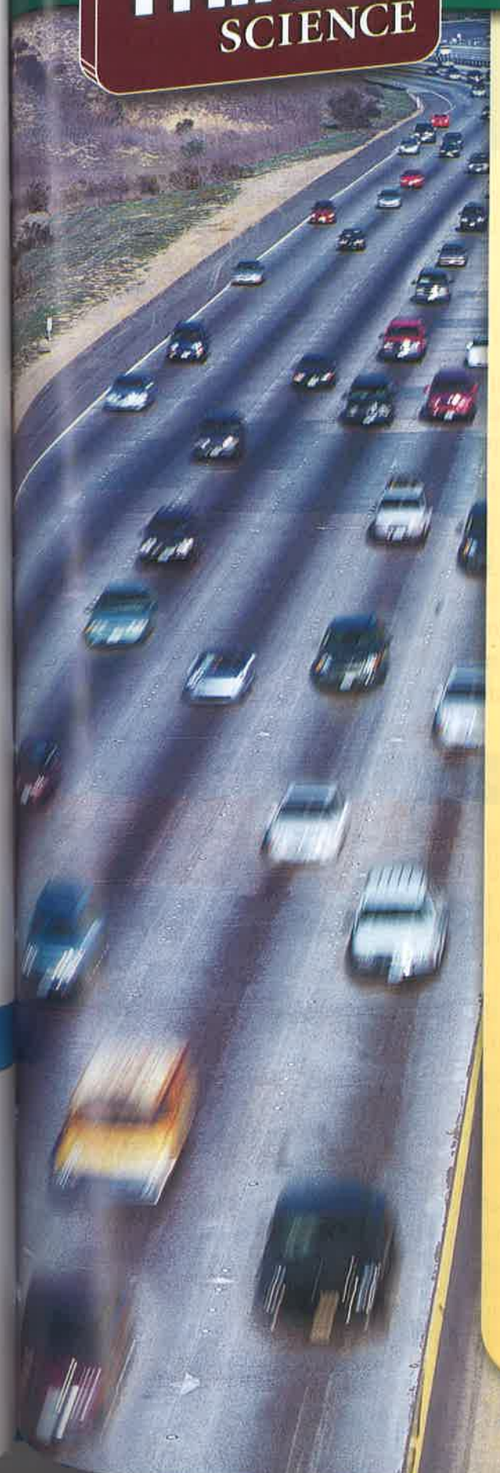
1. List three ways you use energy. How does each example involve a change?
2. What are some changes that can be caused by sound energy? by electromagnetic energy?
3. What two factors determine an object's kinetic energy?

CRITICAL THINKING

4. **Synthesize** How do the different forms of potential energy depend on an object's position or chemical composition?
5. **Infer** What forms of potential energy would be found in an apple on the branch of a tree? Explain.

CHALLENGE

6. **Synthesize** Describe a stone falling off a tabletop in terms of both kinetic energy and potential energy.



Think SCIENCE

SKILL: FINDING SOLUTIONS

Gasoline or Electric?

Cars use a significant amount of the world's energy. Most cars get their energy from the chemical energy of gasoline, a fossil fuel. Cars can also get their energy from sources other than gasoline. For many years, engineers have been working to design cars that run only on electricity. The goals of developing these new cars include reducing air pollution and decreasing the use of fossil fuels. So why have electric cars not replaced gasoline-powered cars?

Advantages of Electric Cars

- Electric motors are more simple than gasoline engines.
- Electric cars use energy more efficiently than gasoline-powered cars, so they are cheaper to operate.
- Controlling pollution at power plants that produce electricity is easier than controlling pollution from cars.
- Electric motors are quieter than gasoline engines.
- Electric cars do not produce smog, which is a major health concern in large cities.

Disadvantages of Electric Cars

- At this time, electric cars can travel only about 120 miles on a single battery charge.
- It takes several hours to recharge the batteries of an electric car using today's charging systems.
- The batteries of an electric car need to be replaced after being recharged about 600 times.
- An electric car's range is decreased by heating or cooling the inside of the car because, unlike batteries in gasoline-powered cars, its batteries are not recharged during driving.

Finding Solutions

As a Group

What technology would need to be improved for electric cars to replace gasoline-powered cars? What facilities that do not exist today would be needed to serve electric cars?

As a Class

Compare your group's solutions to those of other groups. Use the Internet to research hybrid vehicles. How would these vehicles solve some of the problems that you identified?

RESOURCE CENTER CLASSZONE.COM Find out more about electric cars.

KEY CONCEPT

3.2 Energy can change forms but is never lost.

BEFORE, you learned

- Energy causes change
- Energy has different forms
- Kinetic energy and potential energy are the two general types of energy

NOW, you will learn

- How energy can be converted from one form to another
- About the law of conservation of energy
- How energy conversions may be inefficient

VOCABULARY

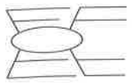
law of conservation of energy p. 82
energy efficiency p. 83

THINK ABOUT

How does energy change form?

Potential energy is stored in the chemicals on the head of a match. The flame of a burning match releases that energy as light and heat. Where does the energy to strike the match come from in the first place?

MIND MAP
Use a mind map to take notes about how energy changes forms.



Energy changes forms.

A match may not appear to have any energy by itself, but it does contain potential energy that can be released. The chemical energy stored in a match can be changed into light and heat. Before the chemical energy in the match changes forms, however, other energy conversions must take place.

Plants convert energy from the Sun into chemical energy, which is stored in the form of sugars in their cells. When a person eats food that comes from plants—or from animals that have eaten plants—the person's cells can release this chemical energy. Some of this chemical energy is converted into the kinetic energy that a person uses to rub the match over a rough surface to strike it. The friction between the match and the striking surface produces heat. The heat provides the energy needed to start the chemical changes that produce the flame. From the Sun to the flame, at least five energy conversions have taken place.

CHECK YOUR READING How is a person's chemical energy changed into another form of energy in the lighting of a match?

Conversions Between Potential Energy and Kinetic Energy

The results of some energy conversions are obvious, such as when electrical energy in a light bulb is changed into light and heat. Other energy conversions are not so obvious. The examples below and on page 80 explore, step by step, some ways in which energy conversions occur in the world around you.

Potential energy can be changed into kinetic energy and back into potential energy. Look at the illustrations and photograph of the ski jumper shown below.

1. At first, the ski jumper is at the top of the hill. This position gives him potential energy (PE) due to gravity.
2. As the ski jumper starts moving downhill, some of his potential energy changes into kinetic energy (KE). Kinetic energy moves him down the slope to the ramp.
3. When the ski jumper takes off from the ramp, some of his kinetic energy is changed back into potential energy as he rises in the air.

When the ski jumper descends to the ground, his potential energy once again changes into kinetic energy. After the ski jumper lands and stops moving, how might he regain the potential energy that he had at the top of the hill? The kinetic energy of a ski lift can move the ski jumper back up the mountain and give him potential energy again.

Changing Potential Energy to Kinetic Energy

READING VISUALS What would the colored bar look like just before the ski jumper lands on the ground?

Using Energy Conversions

People have developed ways to convert energy from one form to another for many purposes. Read about the energy conversion process below, and follow that process in the illustrations on page 81 to see how energy in water that is stored behind a dam is changed into electrical energy.

READING TiP
As you read about the process for producing electrical energy, follow the steps on page 81.

1. The water held behind the dam has potential energy because of its position.
2. Some of the water is allowed to flow through a tunnel within the dam. The potential energy in the stored water changes into kinetic energy when the water moves through the tunnel.
3. The kinetic energy of the moving water turns turbines within the dam. The water's kinetic energy becomes kinetic energy in the turbines. The kinetic energy of the turning turbines is converted into electrical energy by electrical generators.
4. Electrical energy is transported away from the dam through wires. The electrical energy is converted into many different forms of energy and is used in many different ways. For example, at a concert or a play, electrical energy is converted into light and heat by lighting systems and into sound energy by sound systems.

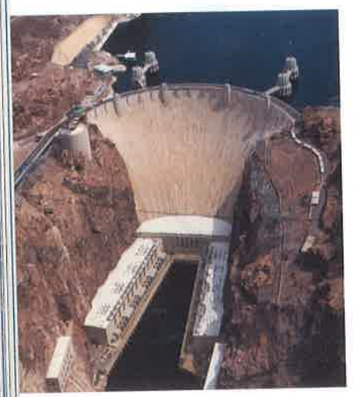
As you can see, several energy conversions occur in order to produce a usable form of energy—potential energy becomes kinetic energy, and kinetic energy becomes electrical energy.

Other sources of useful energy begin with electromagnetic energy from the Sun. In fact, almost all of the energy on Earth began as electromagnetic energy from the Sun. This energy can be converted into many other forms of energy. Plants convert the electromagnetic energy of sunlight into chemical energy as they grow. This energy, stored by plants hundreds of millions of years ago, is the energy found in fossil fuels, such as petroleum, coal, and natural gas.

The chemical energy in fossil fuels is converted into other forms of energy for specific uses. In power plants, people burn coal to convert its chemical energy into electrical energy. In homes, people burn natural gas to convert its chemical energy into heat that warms them and cooks their food. In car engines, people burn gasoline, which is made from petroleum, to convert its chemical energy into kinetic energy.

One important difference between fossil fuels and sources of energy like the water held behind a dam, is that fossil fuels cannot be replaced once they are used up. The energy of moving water, by contrast, is renewable as long as the river behind the dam flows.

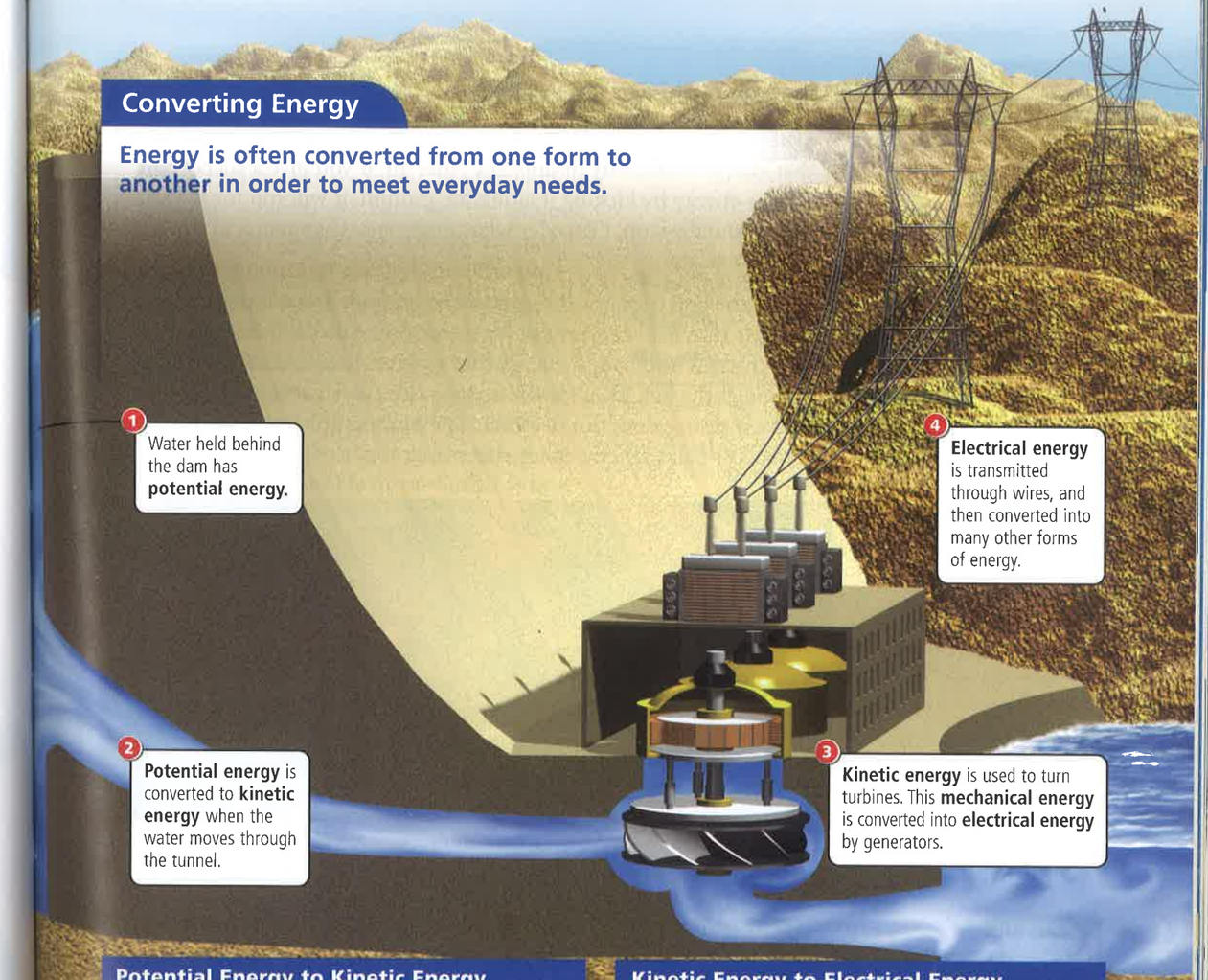
CHECK YOUR READING How can potential energy be changed into a usable form of energy?



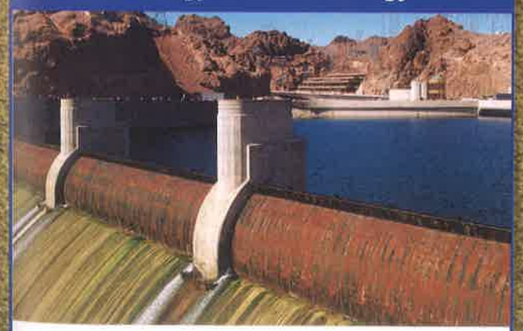
Hoover Dam produces a large amount of electrical energy for California, Nevada, and Arizona.

Converting Energy

Energy is often converted from one form to another in order to meet everyday needs.

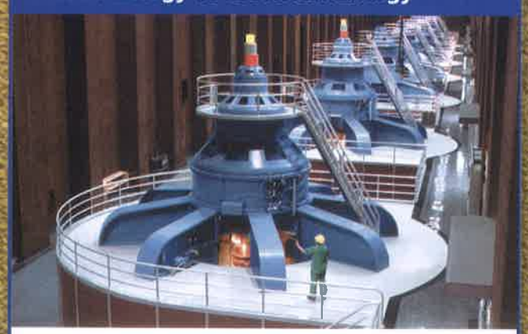


Potential Energy to Kinetic Energy



The potential energy of water behind the dam becomes the kinetic energy of moving water.

Kinetic Energy to Electrical Energy



The kinetic energy of turning turbines becomes electrical energy in these generators.

READING VISUALS How many different energy conversions are described in this diagram?

Energy is always conserved.

When you observe energy conversions in your daily life, it may seem that energy constantly disappears. After all, if you give a soccer ball kinetic energy by kicking it along the ground, it will roll for a while but eventually stop. Consider what might have happened to the ball's kinetic energy.

As the ball rolls, it rubs against the ground. Some kinetic energy changes into heat as a result of friction. Some of the ball's energy also changes into sound energy that you can hear as the ball moves. Although the ball loses kinetic energy, the overall amount of energy in the universe does not decrease. The photograph below shows how the soccer ball's kinetic energy decreases.

The soccer ball's kinetic energy decreases as that energy is changed into sound energy and heat.

In the soccer ball example, the ball loses energy, but this energy is transferred to other parts of the universe. Energy is conserved. The **law of conservation of energy** states that energy can neither be created nor destroyed. Conservation of energy is called a law because this rule is true in all known cases. Although in many instances it may appear that energy is gained or lost, it is really only changed in form.

READING TIP
Conservation refers to a total that does not change.

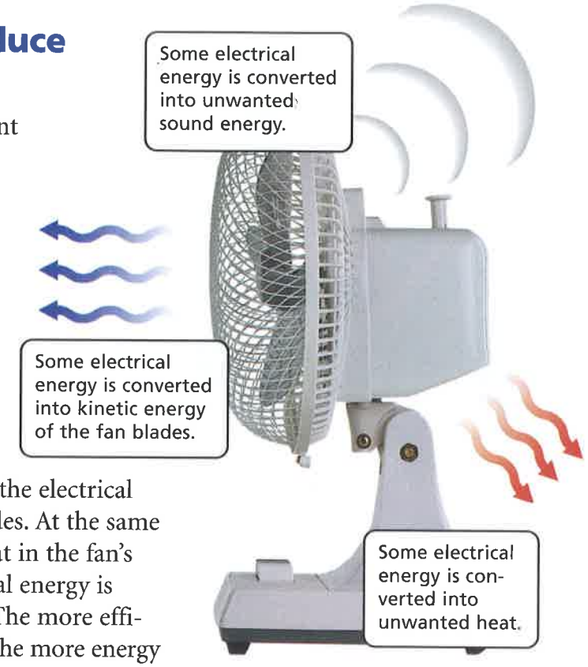
CHECK YOUR READING Explain what is meant by the law of conservation of energy.

Conservation of energy is a balance of energy in the universe. When a soccer ball is kicked, a certain amount of energy is transferred by the kick. The ball gains an equal amount of energy, mostly in the form of kinetic energy. However, the ball's kinetic energy decreases as some of that energy is converted into sound energy and heat from the friction between the ball and the ground.

According to the law of conservation of energy, the amount of energy that a soccer player gives to the ball by kicking it is equal to the energy the ball gains. The energy the ball loses, in turn, is equal to the amount of energy that is transferred to the universe as sound energy and heat as the ball slows down.

Energy conversions may produce unwanted forms of energy.

When energy changes forms, the total amount of energy is conserved. However, the amount of useful energy is almost always less than the total amount of energy. For example, consider the energy used by an electric fan. The amount of electrical energy used is greater than the kinetic energy of the moving fan blades. Because energy is always conserved, some of the electrical energy flowing into the fan's motor is obviously changed into unusable or unwanted forms.



The fan converts a significant portion of the electrical energy into the kinetic energy of the fan blades. At the same time, some electrical energy changes into heat in the fan's motor. If the fan shakes, some of the electrical energy is being turned into unwanted kinetic energy. The more efficiently the fan uses electrical energy, though, the more energy will be transformed into kinetic energy that moves the air.

Energy efficiency is a measurement of usable energy after an energy conversion. You may be familiar with energy-efficient household appliances. These appliances convert a greater percentage of energy into the desired form than inefficient ones. The more energy-efficient a fan is, the more electrical energy it turns into kinetic energy in the moving blades. Less electrical energy is needed to operate appliances that are energy efficient.

CHECK YOUR READING What does it mean when an energy conversion is efficient?

3.2 Review

KEY CONCEPTS

1. Describe an energy conversion you have observed in your own life.
2. Explain the law of conservation of energy in your own words.
3. Give an example of an energy conversion that produces unwanted forms of energy.

CRITICAL THINKING

4. **Synthesize** Suppose you are jumping on a trampoline. Describe the conversions that occur between kinetic energy and potential energy.
5. **Infer** Look at the ski jumper on page 79. Has all of his potential energy likely been changed into kinetic energy at the moment he lands? Explain.

CHALLENGE

6. **Communicate** Draw and label a diagram that shows at least three different energy conversions that might occur when a light bulb is turned on.